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Density Management of Sierra Forests

ABSTRACT

Sierra Nevada forests have been disturbed by fire, mining, and logging. Following this disturbance, forest regenerated naturally or were planted, and as the young conifers grew, they often produced dense stands with considerable competition among trees. This leads to reduced tree vigor and consequently stands become susceptible to major insect attacks. Dense stands also lead to increased fuel loading and potential for fire as trees are killed by insects or competition. Thinning reduces inter-tree competition and it also enables the growth of large trees and the development of mixed species stands. Carefully done thinning, produces commercial yields of wood, stimulates growth of large, insect resistant trees, and diverse stands, while maintaining a forest cover. Care is needed to insure that slash from thinning does not become a fuel hazard and habitat for bark beetles In this section we review the information, relevant to the Sierra Nevada, on the effects of stand density and thinning.

LIST OF FIGURES

INTRODUCTION

Stand density and species composition have a major impact on stand growth and development as well as on many aspects of forest ecology and management. Its of major concern to the Sierra Nevada because there are many stands in the Sierras that began after fire, mining and logging, and often these stands are growing at high densities. Stand density affects, tree growth rates and vigor; cover for wildlife; fuels and fire potential and behavior; understory tree, shrub, and herb density; growth and yield of forest products. The literature on the relationships of stand density, growth, and yield in the 19th and 20th centuries in Europe is comprehensive (Assmann

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1970). Those results have been corroborated by studies in North America (Smith 1986 and Daniel, Helms and Baker 1979). The purpose of this section is to discuss work relevant to the Sierra Nevada forests.

Measures of Stand Density

Several acceptable measures of stand density that have been used in Sierra Forests for many years: stocking (trees/ha), stand density index (number of trees in relation to average tree size) (Reineke 1933), and basal area. These are absolute measures. When they are compared to the maximum a site can support, such as "normal" basal area (Dunning and Reineke 1933, Schumacher 1928, 1930; Meyer 1938) a measure of the degree of full site occupancy is produced that is independent of site productivity, tree species and often age. These measures can be considered standards against which to compare individual stands. More recent studies by researchers at the U.S. Forest Service, Pacific Southwest Research Station, have examined the development of stands growing at a range of densities. They have begun to determine how factors such as tree mortality; growth rates of individual trees and stands; crown size and other stand and tree parameters are related to stand density.

Tree and Stand Growth

As trees grow, stand density increases, trees become more crowded and less resources (water, light, nutrients) are available for maintaining tree and stand vigor. For example, Oliver (In Press) studied the development of a ponderosa pine stand at five densities from stand ages 20 to 40 years on a productive site at 4,000 ft. near Foresthill in the Sierra Nevada. At 20 years of age the densest plots had 507 tree/acre, and 144 ft^2 of basal area; the least dense plots had 77 trees/acre and 64 ft^2/acre of basal area. At 40 years of age, the character of these plots was quite different. In the low density plots, tree diameters averaged 21.2 inches and live crown ratios averaged 70 percent. Values were 13.5 inches and 54 percent, respectively, in the high density plots. In addition, an understory of white fir, Douglas-fir, and sugar pine, and some ponderosa pine became established in the low density plots (Oliver and Dolph 1992).

The density of young stands on productive sites changes much more rapidly than the density of older stands or stands on less productive sites. For example, Oliver (In Press) reports that total basal area growth of the ponderosa pine plots at Foresthill ranged from 4.7 to 9.0 ft^2/acre/year at 21 to 25 years of age and 3.8 to 5.6 ft^2acre/year at 36 to 40 years of age. Thus, these young stands on productive sites increased density very rapidly. Even though they were thinned three times in a 20-year period, net basal areas that ranged from 38 to 144 ft^2/acre at age 20 years had increased to 93 and 190 ft^2 at 40 years. In contrast to Foresthill, a plantation of trees similar in size and thinned to similar densities on a less productive site was growing more slowly. Total basal area growth between the ages of 28 and 38 ranged from 2.2 to 6.6 ft^2/acre/year (Oliver 1979).

Stand densities in red and white fir stands generally are much higher than they are in ponderosa pine stands--320 to 498 ft^2/acre of basal area in one study (Oliver 1988). After reducing stand density to basal areas of 140 to 365 ft^2/acre, this 100-year-old true fir responded to thinning with increased diameter growth. Net basal area growth rates were 3.9 to 6.3 ft^2/acre/year, and it appeared that within about 10 to 15 years these stands would have regrown to their previous densities.

Forest stands maintain a relatively constant rate of biomass production or volume growth rate over a wide range of stand densities. The effects of stand density on stand and tree growth can be generalized from Figure 1. adopted from Smith (1986) and Daniel et al. (1979). At very low densities or numbers of trees per acre, an increase in density causes a proportional increase in volume growth (Zone A). As density increases, volume growth continues to increase but at a lower rate because trees begin to compete with each other for site resources (Zone B). Then growth is constant over a wide range of stand densities (Zone C). However, net growth in Zone C is likely to decrease because mortality is often higher at higher densities. This relationship has been demonstrated for red fir (Daniel, Helms, and Baker 1979; Oliver 1988). Oliver (1988) found that after thinning, net volume growth of true fir stands ranged from 196 to 213 ft^3/acre/year at basal areas of 140 to 170 ft^2/acre. At basal area of 200 to 260 ft^2/acre, growth was somewhat greater-217 to 317 ft^3/acre/year, but no significant relationship existed between stand growth and density over this range of basal areas. Diameter growth, as expected, was significantly greater at lower basal areas. Oliver (In Press) found a similar relationship in the young ponderosa pine plantation at Foresthill. Net or gross volume growth was not significantly related to stand densities that ranged from 51 to 168 ft^2/acre of basal area. Net stand growth across this range of stand densities was 174 to 165 ft^3/acre/year--less at the higher densities because of insect related mortality.

Understory Vegetation and Stand Development

In young stands, stand density and growth may be affected by understory vegetation, particularly shrubs. Also, the interaction of trees and shrubs varies by site productivity. For example, Oliver (1984) found that tree growth in a young ponderosa pine stand on a site of low productivity was related more to manzanita density than to tree density. Once the density of manzanita was reduced, tree and stand growth were regulated by tree density. On a more productive site after 20 years of growth with understories of primarily manzanita and deer brush, trees growing without shrubs were larger and had produced about 40 percent more cubic volume than trees with shrubs (Oliver 1990). Despite covering 77 percent of the area, shrubs appeared to have far less impact than on the less productive site--not preventing stand development but only delaying it. Oliver (1990) estimated that at a 15-foot spacing stands with a shrub understory would have an averaged stand diameter of 12 inches about 7 years later than stands without shrubs.

Stand Density and Insect Populations

There is considerable evidence that the susceptibility of a stand to forest insects is related to its density. However, factors such as drought, root disease, mistletoe, and possibly air pollution also are important. White fir trees under stress from *Fomes annosus* root decay (Ferrell and Smith 1976) and moisture stress from mechanical damage have been shown to be susceptible to the fir engraver beetle. Even sections of individual white fir trees infected by true mistletoe were shown to be under moisture stress and more susceptible to attack than uninfected parts of trees or entire trees (Ferrell 1974). Undoubtedly there is considerable interaction among these variables and stand density. During a severe drought the effects of stand density may become paramount. For example, Ferrell 1980 developed a method of predicting the likelihood of mortality of red and white fir based on crown and bark characteristics. However, when studying the outbreak of the fir engraver beetle that occurred at Lake Tahoe, during the drought of the late 1980's, he found tree characteristics inadequate for predicting mortality on either a tree or stand basis. About 98 percent of the variation in mortality could be explained by models using only white fir basal area and total stand basal area.

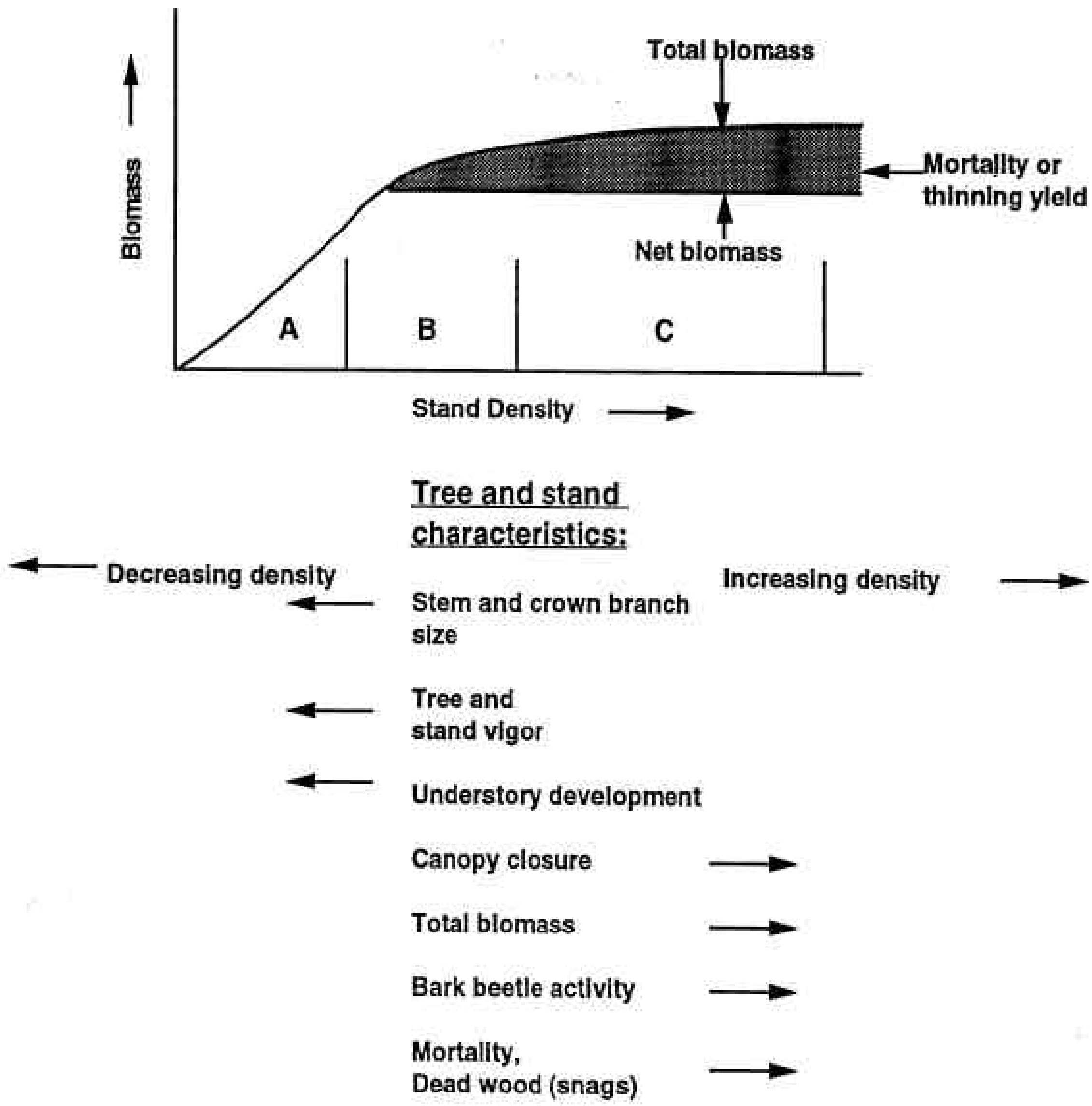

Figure 1. Theoretical biomass production of forest stands, and some tree and stand characteristics in relation to stand density. In zone A, biomass production increases rapidly with increasing density. In zone B, biomass increases with density, but less rapidly than in A, because trees compete with each other. In zone C, there is little increase in net or total biomass with density, but generally more mortality, as density increases, from inter-tree competition

After reviewing the literature on the fir engraver beetle, Berryman and Ferrell (1988), concluded that stand density management to reduce the food supply provided by trees of poor vigor (to the extent that it is practical in western North American forests) may be the best long-term approach to controlling western fir engraver. Other researchers have reached this conclusion for the mountain pine beetle (Waring and Pitman 1985).

Storm damage and related insect mortality have been shown to be related to stand density. At the high stand densities in the Foresthill study at age 40 about 20 percent of the trees had been killed by insects and an additional 5 to 10 percent had been damaged by winter snow and wind breakage (Oliver In Press). Similar storm damage to dense stands was reported by Powers and Oliver (1970). In addition to breeding in trees of low vigor, bark beetles may breed in the broken tops of storm-damaged trees, and then spread to adjacent healthy trees. In a study in northeastern California on a site less productive than that at Foresthill, a range of stand densities was established in a 28 year old ponderosa pine stand. Trees/acre ranged from 43 to 456/acre; basal area from 13 to 86 ft^2/acre. At age 62, approximately 200 trees/acre and about half of the basal area or volume in the high density treatments have been killed by bark beetles.

Stand Density Management

Total biomass or volume production generally increases with stand density. However, tree mortality, caused by inter-tree competition, insect mortality and storm damage (as discussed above) also increases with density. Of course, tree size and vigor increase as competition (i.e. stand density) decreases. It is important to stress that net production or yield of wood is relatively constant beyond a certain density (Zone C)(Figure 1).

Other variables important to forest management are related to stand density. A productive understory-- conifers, hardwood and shrubs, herbs, grasses-- generally becomes established in stands of low density with few overstory trees. This affects forage for wildlife and livestock and also cover for wildlife. However, in more open stands understory vegetation and the large crowns of the trees may result in high fuel loads and fire potential unless the crowns are pruned and understory density is reduced (by grazing, cutting, burning, or herbicides). In dense stands, dead trees will increase fuel loading from snags and logs on the forest floor. Although snags and logs are important habitat for some wildlife species, dead trees in very dense stands will likely be too small to provide cavities or to persist as snags or logs on the forest floor.

Objectives for regulating stand density in Sierra Nevada forests are ecological, as well as managerial. These include reduction of fuels and fire potential, regulation of species composition, enhancing the development of large trees, wood production, and regulation of the understory of shrubs and conifer regeneration. Most of these objectives are "interactive". For example, thinning to develop fire resistance by reducing overstory density and fuel ladders of understory shrubs and conifers also will tend to reduce susceptibility to insect-caused mortality, and to accelerate development of old-growth characteristics, i. e. large trees with full crowns. Thinning will yield merchantible wood, as well. Shade-tolerant conifers, however, will likely regenerate in the understory of these stands. Periodic underburning or mechanical tree removal would be needed to retain fire resistance.

Regulation of species composition is a compelling part of density management. White fir, incense cedar and to a lesser degree, Douglas-fir, are shade-tolerant species that are easily established beneath an overstory. In the absence of fire, during the 20th century, they have undoubtedly contributed to increased stand density. In addition to increasing fuels and fuel ladders, these species compete with large ponderosa and sugar pine. They also increase shade within stands and thereby reduce the likelihood of natural pine establishment.

The desired density of forest stands depends upon management objectives, site productivity, species composition and age of the stands, and frequency of treatments. Stands that are being managed for spotted owls would undoubtedly have relatively dense overstories, as well as multiple understory layers. Whereas, those for which the objectives were reduced fuels and fire potential would be open with few trees and shrubs in the understory. For a given site quality or potential productivity, mixed conifer stands would be denser than ponderosa pine stands.

Managing stand density by thinning needs considerable planning and care. Slash resulting from thinning can be a fire hazard. Also, if stands are thinned in the spring, fresh slash may be habitat for bark beetles (populations of which could build up in the slash and then move to green trees). Not all snags, slash, or trees of poor vigor need to be removed. Some should be left for species that use cavities or depend upon dead wood. However, the abundance of dead wood that is left should not be sufficient to encourage build-up of bark beetles nor become hazardous fuels.

Timing treatments to the rate of stand development is an important consideration in density management of forest stands. The rate of stand development and future stand density and vigor must be anticipated. For example, young stands of ponderosa pine grow rapidly. If they become very dense, crowding causes individual tree crowns' size and density to decrease. In this condition, in addition to stands becoming more susceptible to insects, diameter growth decreases and height to diameter ratios increase. Thus, crowded stands are susceptible to snow and wind damage especially after thinning. According to Oliver (In Press) thinning regimes kept live crown ratios (percent of tree boles with crowns) from about 55 to 75 percent. All trees responded well to thinning although the western pine beetles were active in plots at high densities.

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